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ABSTRACT

This volume of the final report for the Robotics/Automated Systems Technician (RAST) curriculum project is a curriculum planning guide intended for school administrators, faculty, and student counselors/advisors. It includes step-by-step procedures to help institutions evaluate their community's needs and their capabilities to meet these needs in the area of RAST training. Chapter I describes robotics/automated systems technology. Brief explanations of the components of robots and automated systems are provided. The special capabilities distinguishing these systems from traditional manufacturing equipment are listed and described. Current applications are catalogued briefly. Chapter II provides information about the expected future demand for RASTs and recommendations for conducting local and regional needs surveys. Chapter III provides a job description and task analysis for the RAST. Chapter IV describes the rationale, structure, and content of a recommended RAST training program. The core curriculum approach is explained and the national model for a RAST curriculum is described. Course descriptions, outlines, and a suggested sequence are included. Recommendations and information regarding program planning and implementation are contained in chapter V. Facilities and equipment, staffing, costs, and entrance guidelines are considered. Appendixes include specialty course outlines and a listing of textbooks and references. (YLB)

Robotics/Automated Systems TECHNICIAN TRAINING

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FINAL REPORT

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FINAL REPORT

VOLUME 2

CURRICULUM PLANNING GUIDE

Project No. 051MH30009

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TASK ANALYSIS AND DESCRIPTIONS OF REQUIRED JOB COMPETENCIES FOR ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

Daniel M. Hull James E. Lovett

Center for Occupational Research and Development

Waco, Texas

April 1985

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UNITED STATES DEPARTMENT OF EDUCATION

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Division of National Vocational Programs

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FOREWORD

For more than a decade, American manufacturing has steadily lost ground to overseas production. While debate continues over the economic causes of this loss (overvalued dollar, trade agreements, etc.), there is general agreement among industry, government and labor that U.S. manufacturers must increase productivity.

For more and more industries, the productive edge required to maintain foreign and domestic markets is being achieved through automation. Robotics and automated systems technology, creatively applied to support human endeavor, has the potential to restore American manufacturing to a forward position in the world market. Furthermore, significant gains in productivity require more than automation of the most obvious processes in the most obvious way. Besides the imagination and persistence of those in management, trained technical support staff are needed for the implementation, maintenance, and continued flexible operation of robots and automated manufacturing systems.

The United States Department of Education, Office of Vocational and Adult Education, issued a contract to the Center for Occupational Research and Development to develop a model curriculum that schools could use as a guide when establishing a new program or modifying an existing one. The curriculum is based upon a core of courses that are common to training technicians in advancing-technology fields. This core includes courses such as math, science, communications, fundamentals of electricity and electronics, electromechanical devices, mechanical devices and systems, instrumentation and control and computers.

Six specialty courses designed to build upon the broad-based interdisciplinary core are: Fundamentals of Robotics and Automated Systems, Controllers for Robots and Automated Systems, Automated Systems and Support Components, Robotics/Automated Systems Interfaces, Robotics/Automated Systems at Work, and Automated Work Cell Integration. Each course was developed to the extent of having four to seven module outlines. Each module is specific to one portion of the course and can be taught independently, but in sequence with the other modules.

The Final Report for this project is written in two volumes. Volume 1 describes the processes followed in the development of the model Robotics/Automated Systems Technician curriculum. Volume 2 is a Curriculum Planning Guide--containing task listing, detailed curriculum/course designs and a recommended procedure that institutions and schools can follow when establishing or modifying a Robotics/Automated Systems Technician Training program.

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CHAPTER I: ROBOTICS/AUTOMATED SYSTEMS TECHNOLOGY: DEFINITION AND DESCRIPTION

This chapter of the guide describes robotics/automated systems technology. Brief explanations of the components of robots and automated systems are provided. The special capabilities that distinguish these systems from traditional manufacturing equipment are listed and described. Finally, current applications of robotics/automated systems technology are cataloged briefly.

Robotics and automated systems technologies unite conventional (though sophisticated) machine capabilities with the science of computer programming. The basis of manufacturing is the shaping, joining and coating of materials: this can be accomplished by cutting, casting, molding, grinding, welding, painting, and electrical processes. Prior to the mid-50s, the machine tools that perform these tasks had changed little since the 1900s.[1] In the past three decades, however, significant changes have been made--quantitatively, in the improvement of "traditional" electrical, pneumatic, and hydraulic equipment--and qualitatively, in the introduction of electronic control systems and electro-optic devices and systems. The combination of modern machine tools and electronic controllers has yielded robots and automated systems technology.

In the popular media, robots are often compared to human beings, and much is made of the growing capabilities of robots. In fact, robots are no more or less than assemblies of electrical, pneumatic, electronic, and/or hydraulic manipulators and mechanisms. These components are connected to and controlled by a programmable controller, as indicated in Figure 1, to perform specific tasks. In modern robots the controller can be reprogrammed whenever needed, allowing the robot to perform a variety of tasks. Most robots are elements of a total production system, which may be totally or only partially automated. Automated systems, such as the workstation shown in Figure 2, are also assemblies of manipulators and mechanisms, similar to those in robots and controlled by a microprocessor or computer to accomplish several tasks rapidly. In summary, both robots and automated systems are assemblies of similar components and mechanisms, and robots may work as part of an automated system.[2]

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[1]David Hamilton. Technology, Man, and the Environment. London: Faber and Faber, Ltd., 1973.

[2]Dan Hull and James Lovett, "An Assessment of the State of the Art of Curriculum Materials and a Status Assessment of Training Programs for the Robotics/Automated Systems Technicians, Waco, TX: CORD, May 1984, p 3.

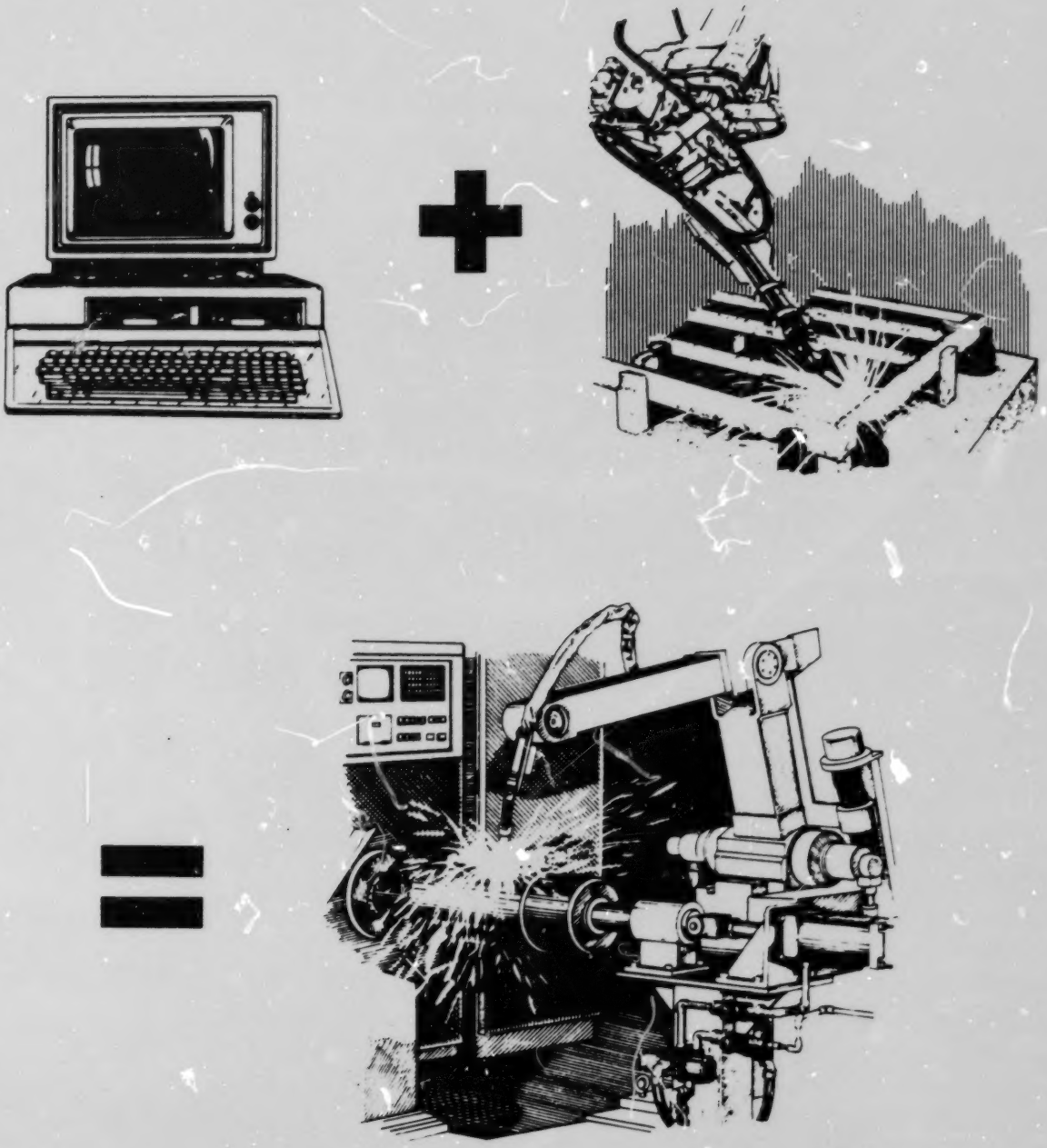

Fig. 1 Electronic control + modern machine tools = robots.

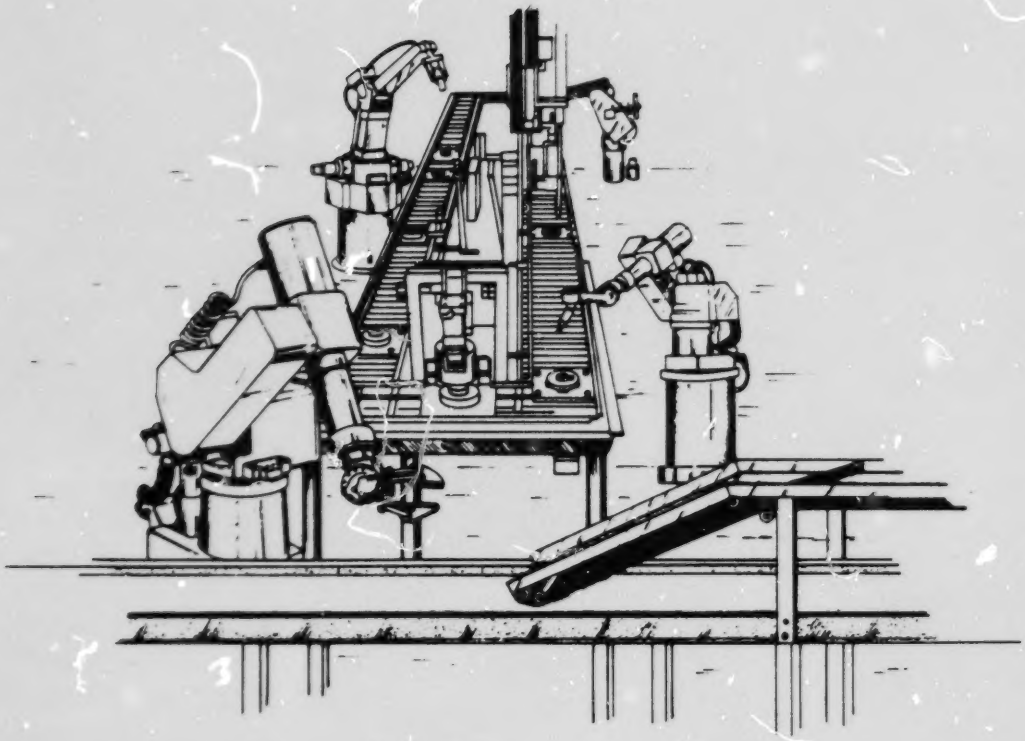

Fig. 2 Automated workstation.

THE COMPONENTS OF ROBOTS AND AUTOMATED SYSTEMS

Robots and automated systems generally are comprised of microprocessors or controllers (the computer and programmed instructions), actuators (electromechanical, hydraulic or pneumatic devices that do the work), transducers (sensing and measuring devices), and supporting structure.

Microprocessors tell the robot or automated equipment what to do. Some robots are programmed "on-line"; that is to say they are programmed at the work site by a technician who is familiar with the process to be performed. The controller is in the program mode while the robot arm is moved, and thousands of points may be entered automatically into the memory as the robot is manipulated through its motions.[3] This way of programming a robot is known as "lead-through"; it is often carried out by a worker who knows the task very well, having performed it manually. "Off-line programming" is usually carried out by someone who is more removed from the shop floor operations; this kind of programming allows for the use of sensors and for the robot to

[3]Rita R. Schreiber, "How to Teach a Robot," Robotics Today, (June 1984) pp 51-56.

be integrated more easily into a total manufacturing system. Off-line programming requires programming skills, including a knowledge of robot programming languages.[4]

The actuators of a robot or automated manufacturing system carry out programmed operations. Electronic signals generated by the microprocessor activate switches and relays, which in turn activate motors and other electromechanical devices such as drives, gears, and pumps. In robots, there are two main types of actuators: those that are within the main body of the robot and those that are positioned at the end of the robot arm, known as end effectors; examples of end effectors are shown in Figure 3. The main body of the robot may be bolted to the floor, mounted on a track, or hung from overhead supports. Hydraulic, pneumatic, or electrical mechanisms may be used to move the robot arm. The robot's dexterity (and cost) is determined partly by its degrees of freedom.[5] The task to be accomplished--welding, cutting, grinding, etc.--is carried out by the tool it carries, which may be a welding gun, high-pressure water jet, laser, mechanical gripper, vacuum gripper, drill, riveter, or other machine tool.

Fig. 3 Different types of end effectors, grippers, arc welding equipment, etc.

[4]Ibid.

[5]Marjory Blumenthal and Jim Dray, "The Automated Factory: Vision and Reality," Technology Review, Jan. 20, 1985, p 34.

Sensors measure, among other qualities of objects, the presence or absence of those objects or motion near the robot. Sensors range from simple detectors to relatively sophisticated measuring devices. Many sensors involve the transmission of light or sound to the object or part to be measured or inspected. The light or sound is then reflected from the part in question to an instrument such as a photodetector or an acoustic receiver. Eventually, the information received in the form of light or sound must be converted into electrical signals that can be processed by the circuitry of the microprocessor. Other sensors measure or detect pressure, force, liquid flow, or temperature--and again, convert information received about these qualities or conditions to electrical signals.

THE CAPABILITIES OF ROBOTS AND AUTOMATED SYSTEMS

The capabilities that set apart robotics and automated manufacturing systems from traditional manufacturing techniques include the following:[6]

Capacity for Information Processing

Robots and other elements of automated systems can be produced with the capacity to process information as well as to do physical work. Through the use of light detectors, tactile sensors, and other sensing and measuring devices, automated equipment can be made to adjust performance to satisfy specific conditions. For example, in the precision forging of jet engine airfoils, a robot equipped with two infrared sensors can detect whether or not the forged part has been properly ejected from the die; furthermore, the robot's subsequent actions will be carried out in response to the processed information.

Quality Enhancement

Robots are capable of quality enhancement through reliability, precision, and adaptive control of the production process. For example, in one automotive plant, the trimming of foam and vinyl from dashboard components was once carried out manually with a knife. It was a time-consuming process; uniform quality was difficult to obtain; and mistakes could result in a scrap part or operator injury. Now excess plastic is removed by a computer-controlled robot equipped with a laser cutting tool. The robot can perform this task with consistent accuracy, resulting in a product of higher quality.

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[6] Office of Technology Assessment, Congress of the United States. Automation and the Workplace. Washington, DC: 1983, p 4.

Reprogrammability

Robots and automated systems, unlike conventional manufacturing systems, can be reprogrammed for application to the production of a diverse mixture of products. For example, a manufacturer of naval helicopters now uses the same automated system (including a track-mounted robot, an integrated fixturing system, a multipurpose end effector and rivet delivery system, and a computer-command and control system) to perform drilling, sealing, and riveting operations in the assembly of various helicopter components and subassemblies. The system is flexible enough to allow for these diverse operations and is considered reprogrammable for the production of other aircraft components as well.

Capacity for Integration

The capacity exists for integrating production systems (including robots) and equipment with each other and with design, analysis, inventory control, and other aspects of the manufacturing process. In the purest form, such production systems are directed entirely from the computer terminal, with the intervention of only a small number of skilled workers to maintain equipment; this is the "factory of the future" often referred to in the media. In reality, integration is usually seen in a subsection of a factory known as a flexible manufacturing system (FMS).[7] An FMS may include computer-controlled machine tools, grinders, heat-treating machines, assembly and inspection equipment. Parts may be moved from one workstation to another by means of conveyors, monorails, or other automatic material-handling devices. The entire FMS is controlled by computer, and manufacturing operations can be altered by program changes.

APPLICATIONS

Robotics and automated manufacturing systems are being implemented at such a rate that it is difficult to convey the scope of current applications. In the early years of their development, robots were used in relatively simple operations such as very basic pick-and-place tasks, paint-spraying, or spot-welding. The first robot applications in many industries were those that involved hostile environments, hazardous materials, or other safety and health risks. Today the emphasis is on increased productivity in a variety of applications, including more complex operations. The following list of

[7] Blumenthal and Dray, Technology Review, Jan. 20, 1985, p 34.

current applications is taken from operations cited in Robotics Today during the last three years:

Paint spraying of auto bodies in fully automated system (General Motors Corporation)

High-speed arc-welding of automobile frame components (Ford Motor Company)

Parts trimming of automobile dashboards by laser-equipped robot (Ford Motor Company)

Assembly of word processing system (Displaywriter, IBM)

Assembly of electrical power connectors to solar cell modules (Jet Propulsion Laboratory, California Institute of Technology)

Loading and unloading of workpieces in a flexible manufacturing system (auto parts manufacturer, England)

Metal cutting of fuel tank shields by water jet systems installed on robots (General Motors Corporation)

Drilling and riveting of airframe structures (Sikorsky Aircraft)

Finishing operations (including drilling and removal of internal burrs) on molded plastic housings (ASEA, Sweden)

Inspection for surface cracks and flaws in precision castings, forgings, and other components (Magnaflux robot, unidentified company)

Precision forging of jet engine airfoils (General Electric)

Other applications include but are not limited to: **soldering, gluing, coating, sealing, palletizing, sorting, packaging, labeling, and cleaning.**

Applications Other Than Manufacturing

The range of activities subject to programmable automation is not limited to the fabrication and assembly of products.[8] Already many aspects of service and information industries have been affected by the technology of robotics/automated manufacturing: printing, office management, telephone communications, and marketing and distribution, to name a few. Other areas of application are likely to be discovered and/or expand their use of robotics/automated manufacturing, including research and development, medical testing and monitoring, product servicing, and aspects of management in every sector of the economy.

Anything We Can Do, Can Robots Do It Better?

The length and breadth of the list of applications cited naturally raises larger questions about the capabilities of robots and the functions of human workers in automated manufacturing. Current research in the areas of

[8] Automation in the Workplace, p 12.

artificial intelligence and visual and tactile sensing is likely to increase the areas of robot activity. However, for the time being, industrial robots are very limited compared with human workers.[9] As two researchers, Blumenthal and Dray, point out, "Manufacturing operations may seem simple--until you try to reduce them to computer programs."[10] The task ahead is to apply automated systems and robots where they can be most effective in increasing productivity, improving product quality, reducing energy consumption, and eliminating workplace hazards to human workers. At the same time, the challenge is to train workers and organize tasks so that the considerable and unique capabilities of human beings are fully employed. Again, Blumenthal and Dray urge the point that "it is important to develop machines that people can work with effectively, and to identify the points where human responsiveness and creativity can contribute most." Coming to the problem of human/machine interaction from another perspective, educators have to train technicians who understand the principles of machine operations, who are knowledgeable and flexible about when and how to intervene.

[9]Blumenthal and Dray, Technology Review, Jan. 20, 1985, p 32.
[10]Ibid.

CHAPTER II: PROJECTED WORKFORCE NEEDS

This chapter of the guide provides information about the expected future demand for Robotics/Automated Systems Technicians. The emphasis is not upon fixed projections but on known information and general trends. Recommendations for conducting local and regional needs surveys are provided, also.

SUMMARY OF WORKFORCE NEEDS AND CURRENT PROGRAMS

Robotics and automated manufacturing technology are key factors in the ability of the United States to maintain a competitive position in the world marketplace. As indicated in Chapter I, the applications for (re)programmable automated systems go beyond the manufacturing sector. Robots perform many tasks other than the classical--hot, heavy, and hazardous jobs.

Overview

Activities that are affected by robotics/automated systems technology may be considered in two main categories: production activities and use activities.[11] Production activities refer to the manufacture of robotics/automated systems equipment--the computer hardware and software associated with its use as well as machine tools and other adaptations of conventional factory equipment. Within the area of production activities, jobs are likely to be created in manufacturing (design engineering, production, technical support), maintenance, sales, service, installation, clerical, and marketing activities.

Use activities include all the areas in which robotics and automated manufacturing are applied--except for the production of the technology itself. Within particular industries or companies both production and use activities may take place. The areas of application are numerous: assembly (both large and small parts), parts sorting, palletizing, parts stacking, counting, and other material handling activities; a range of manufacturing activities including welding, grinding, cutting, trimming, coating, spray-painting, buffing, and soldering; inspection and testing activities; and others.

How can the effects of robotics/automated systems technology on employment be determined? The variety and extent of applications of this technology create uncertainties about future labor market demands, and estimates abound but vary dramatically. Experts do agree that many jobs will be created and also that many jobs will be eliminated. And, although there is vast

[11] Automation and the Workplace, p. 12.

disagreement about the size and shape of the workforce of the future, most everyone agrees that it needs to be better educated and technologically literate.

HELP WANTED: Robotics/Automated Systems Technicians (RAST)

There are, at the present time, approximately 4,000 robots working in factories; by 1990 an estimated 150,000 robots will be installed and working.[12] Technicians will be required to install, set up, calibrate, operate, service, and maintain these robots and the automated systems where they are used. Robotics/automated systems technicians must be competent in hydraulic, mechanical, electrical, thermal, and pneumatic systems, programmable controllers, sensing systems, safety, vision systems, and controller communications techniques and systems. The efficient operation of modern manufacturing industries requires new, advanced-level systems technicians.

For the most part, the "supertechs" that are described above do not exist in today's industries, and it will be very difficult to produce them by retraining existing craft workers from the electrical and mechanical trades. To temporarily fill this job need in many instances, engineers are pressed into service as technicians, a very expensive practice that robs the industry of much of its design capability.

The need for RASTs is certain to increase. Based on a study by Donald Smith for the University of Michigan and the Society of Manufacturing Engineers, there will be a need for 11,000 to 15,000 robotics technicians by 1990.[13] To provide for this projected need, comprehensive, broad-based robotics technician training programs must be working to educate new technicians in a manner that ensures their employability.

Current Training of RAST

In May of 1984 the Center for Occupational Research and Development (CORD) completed a report on existing RAST training programs in postsecondary public and private schools.[14] Based on survey results provided to CORD by RI/SME, indications are that 56 institutions have RAST programs in place and 17 more are developing new programs. The number of students currently enrolled is 5472, and approximately 2200 students may graduate each year from existing programs (allowing for attrition and predictable delays). Thus the

[12]Ibid, pp 15, 16.

[13]Donald Smith and Richard Wilson. Industrial Robots - A Delphi Forecast of Markets and Technology. Society of Manufacturing Engineers, 1982.

[14]Hull and Lovett, Assessment.

current projected enrollment levels at schools with existing and planned programs may be sufficient to meet the projected need of 11,000 to 15,000 technicians in this field by 1990. However, the nature of almost all of these programs is neither comprehensive nor broad based. In many cases, programs are short-term; most are not competency-based and many do not emphasize hands-on learning. Some programs teach a very narrow specialty area within the field of robotics/automated sustems. Very few existing programs are training RASTs to be versatile and able to install, set up, operate, maintain, program, troubleshoot, repair, test and calibrate any robot or automated system that their future employer may elect to design or purchase. Therefore labor force requirements for adequately prepared RASTs are not likely to be satisfied by the end of this decade.

This conclusion seems to be echoed by industry leaders. At a 1982 seminar entitled "Robotics and the Factory of the Future," business representatives emphasized the problem of training and the need for future workers to develop marketable skills. One speaker called the training problem "a real bottleneck in the race to automate."[15] Another commented that industry training time is longer than anticipated, and that refresher courses are often needed.[16] Both of these problems can be interpreted as a result of the lack of broad-based, adequate training at the school level.

LOCAL AND REGIONAL NEEDS SURVEYS

Most forecasting is based on either engineering estimates or economic estimates. Engineering estimates involve comparing new automation capabilities with human ones, and correlating the relevant tasks to occupational categories. Economic estimates of employment change are made by evaluating such factors as prices and production levels.[17] Both engineering and economic estimates may prove helpful, but forecasting is considered by many to be--at its best--imprecise. Although educators and industry leaders are compelled to pay attention to the numbers, ideally, their knowledge of statistics is balanced by a deeper understanding of changes in labor force requirements and a close knowledge of industry needs within their own community and region.

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[15]Rita R. Schreiber, "Robotics in the Eighties," Robotics Today, October 1982, p 42.

[16]Ibid.

[17]Automation and the Workplace, p 17.

Although some firms may recruit RASTs from campuses outside their geographical area, the major sources of jobs are usually within or adjacent to the state. Some firms are reluctant to cover interviewing and moving expenses for employees at the technician level and, in many cases, students are unwilling to relocate long distances. Administrators are advised to survey employers within the home state and surrounding region. A survey instrument suitable for such a workforce needs assessment is included in Appendix A. The implementation of such a survey should be supported by assistance from an advisory committee of educators and industry representatives. (The entire investigative process that an educational institution can undertake to assess the feasibility of a RAST program is discussed more fully in Chapter V of this guide and in the Advanced-Technology Core Curriculum Guide.*) The survey should yield information about the projected and actual workforce needs within a region, the fields of specialization in which training is most needed, and the starting salary distribution.

*Available from Center for Occupational Research and Development, Waco, Texas 76710 (800/231-3015)

CHAPTER III: KNOWLEDGE AND SKILLS FOR ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

This chapter of the guide provides a job description and task analysis for the prospective Robotics/Automated Systems Technician. These materials were originally developed by the Center for Occupational Research and Development under contract with the U.S. Department of Education, Office of Vocational and Adult Education. Throughout the project--the scope of which was to design a model RAST curriculum and generate course and module outlines--CORD was guided by an independent National Advisory Committee. The Committee was composed of robotics experts from industry (manufacturers and users of robots), education and labor.

JOB DESCRIPTION

The responsibilities of Robotics/Automated Systems Technicians are defined as follows:

> Robotics/Automated Systems Technicians are technical specialists with broad-based electromechanical skills who are familiar with electronic, mechanical, hydraulic and pneumatic devices. They are usually specialists in robotics or automated equipment and can set up automatic machines that work together as part of a total automated system. In their area of specialization, they can install, set up, troubleshoot, integrate, program, modify, test, operate, and repair systems and components. They are field-service, installation or service technicians. They will work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

In their respective jobs, the technicians may have several job titles including Robotics Technician, Automated Systems Technician, Maintenance/Robots, Electromechanical Technician or Robotics/Automated Systems Technician. These titles cannot be correlated to specific duties due to the diversity of job titles and job descriptions in industry today.

TASK ANALYSIS

The following is a list of the tasks--expressed as student competencies--that employers expect technicians to be able to perform. The tasks have been classified according to the major discipline with which they are associated. The tasks are further divided into terminal and enabling competencies. A terminal competency is a specific, definable task a technician must be able to perform as a part of normal work routine. An enabling competency is one that is all or part of the basis for a technician being able to

perform a terminal competency. The enabling competency may be either 1) having the ability to perform a simple task or 2) knowing facts that allow interpretation of specific data related to a terminal competency.

ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN
Task Listing

Electrical/Electronic

Terminal Competencies

1. Use manufacturers' parts list and drawings concerning replacement parts for robots/automated systems to
   a. Identify part numbers
   b. Order replacement parts
   c. Install replacement parts
2. Adjust, troubleshoot, repair, and/or replace:
   a. Power supplies
   b. Servo amplifiers
   c. Motor control circuits
   d. Electronic sensors
   e. Transducers
3. Attach and replace connectors to wire and fiber-optic cables.
4. Install low- and high-voltage and interconnecting signal (wire and fiber-optic) cables.
5. Troubleshoot and repair wire and fiber-optic system cable faults.
6. Conduct routine preventive maintenance on electrical and electronic equipment in accordance with manufacturer's recommendations.
7. Troubleshoot electronic failures to the circuit board level; replace defective circuit board.
8. Conduct routine preventive maintenance on ac and dc motors in accordance with manufacturer's recommendations.
9. Install, adjust, troubleshoot and repair or replace to manufacturer's specifications:
   a. Control devices
   b. Relays (electromechanical and solid state)
   c. Sensors
   d. Limit switches
   e. Transducers
   f. 1-Φ and 3-Φ electrical equipment
10. Connect fiber-optic cables to electronic equipment.
11. Troubleshoot, repair or replace fiber-optic components/systems.
12. Program stepper motors.
13. Apply bridge circuits to measuring voltages and currents.
14. Replace components on circuit boards.
15. Solder and desolder electrical connections.
16. Install and remove circular (multipin), coaxial, and in-line plugs and receptacles.
17. Measure and set voltages and currents.
    a. Facility power
    b. Equipment power supply

Enabling Competencies

1. Read schematic diagrams.
2. Read wiring diagrams.
3. Interpret industrial electrical symbols and line diagrams from printed material and/or graphic display systems.
4. Describe in writing how switches and solenoids work.
5. Describe in writing SCR controls.
6. Analyze series and parallel circuits.
7. Use operational amplifiers as followers, inverters, summers, integrators, and differentiators.
8. Use an oscilloscope to determine wave forms.
9. Determine signal frequency.
10. Describe ac and dc current flow.
11. Describe lead acid battery construction.
12. Describe ac and dc electric motor operation.

Pneumatic

Terminal Competencies

1. Maintain pressure regulators.
2. Install, adjust, troubleshoot and repair or replace pneumatic:
   a. Airlines
   b. Pumps
   c. Gages
   d. Filters
   e. Control valves
   f. Actuators
   g. Cylinders
   h. Pressure switches
   i. Positioner relays
3. Adjust a pneumatic-sensor temperature controller to a specified mixed air temperature.
4. Properly use dampers, thermostats, switches, pneumatic positioners, linkage assemblies and accessories in pneumatic systems.
5. Conduct routine preventive maintenance on pneumatic equipment in accordance with manufacturer's instructions.

Enabling Competencies

1. Sketch flow path symbols and air logic drawings.
2. Interpret flow path symbols and air logic drawings.
3. Identify and use proper size of pneumatic piping.

Hydraulic

Terminal Competencies

1. Install, adjust, troubleshoot, and repair or replace hydraulic:
   a. Lines
   b. Pumps
   c. Gages

d. Filters
e. Accumulators
f. Volume controls
g. Servo valves
h. Directional control valves
i. Pressure control valves

2. Test for hydraulic oil quality and use external filter system to purify.
3. Control oil pressure and temperatures.
4. Null hydraulic servo systems.
5. Calculate hydraulic system pressure losses.
6. Conduct routine preventive maintenance on hydraulic equipment in accordance with manufacturer's specifications.

Enabling Competencies

1. Identify and use proper size lines.
2. Describe the relationship between hydraulic pressure and flow.

Mechanical

Terminal Competencies

1. Set and adjust mechanical stops.
2. Set actuators to proper end positions.
3. Install and maintain linkage.
4. Install and maintain gear trains.
5. Conduct routine preventive maintenance on mechanical equipment in accordance with manufacturer's specifications.

Enabling Competencies

1. Identify elements used in selection and design of processes that can be automated.
   a. Welding
   b. Painting
   c. Material handling
2. Determine speed and torque ratios.

Computer

Terminal Competencies

1. Troubleshoot malfunctions in computer system to circuit board level.
2. Install, troubleshoot, remove and replace:
   a. Memory devices
   b. Displays
   c. Control circuits
   d. Keyboards and printers
   e. Central processing unit (CPU)
   f. Interface modules

3. Install input/output (I/O) devices in accordance with manufacturer's specifications:
   a. Cathode-ray tubes (CRT)
   b. Printers
   c. Tape drives
   d. Disk drives
   e. Plotters
   f. Flat screen displays (including gas plasma displays)
4. Install module or board-mounted RAM and ROM memory devices in accordance with manufacturer's specifications.
5. Load and run diagnostic routines.
6. Interpret diagnostic printouts.
7. Install programmable controllers.
8. Use diagnostic routine program language written in machine language(s).
9. Program and/or reprogram PCs (drum, relay, and microprocessor types) for specific sequence of events in performing an application.
   a. Prepare a flow chart for a specific sequence of events in performing a given application.
   b. Enter instructions into control unit.
   c. Run program to see if control unit executes properly.
   d. Edit or debug program as necessary.
   e. Download and upload system.
   f. Recognize and resolve hardware/software impedance matching problems.
10. Write, enter, and debug programs in one structured language.
11. Install, set up, calibrate, troubleshoot and repair or replace data transmission systems.

Enabling competencies

1. Characterize digital circuits.
2. Describe microprocessor input/output characteristics.

Electromechanical

Terminal Competencies

1. Install, adjust, troubleshoot and repair or replace:
   a. Servo motors
   b. AC pump motors (vacuum and pressure)
   c. Speed reduction units
   d. Clutches
   e. Stepping motors
   f. Mechanical drives for feedback system
2. Install, adjust, troubleshoot and repair or replace sensors for:
   a. Flow control
   b. Liquid-level control
   c. Ultrasonic control
   d. Optoelectric
   e. Tactile
   f. Video

Enabling Competency

1. Describe the applications of the following systems to a robotic work cell:
   a. Hydraulic--electrical--pneumatic positioners and sensors
   b. Motor drives and servos
   c. Control systems including feedback
   d. Mechanical linkages/gears
   e. Electrical power system

General

Terminal Competencies

1. Effectively select and utilize such test equipment as time-domain reflectometers, oscilloscopes, spectrum analyzers, function generators, chart recorders, and multimeters for troubleshooting and repair of electronic circuits.
2. Identify and demonstrate proper operation, care and maintenance of hand power tools.
3. Select and install the proper fastener for a given job.
4. Identify and use appropriate lubricant.
5. Use manual's troubleshooting charts to aid fault isolation/repair.
6. Maintain work log sheets.
7. Draw logic diagrams.
8. Read, understand and comply with requirements of service bulletins.
9. Convert measurements between English and SI systems.
10. Use both inside and outside micrometers.
11. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.
12. Use manufacturer's manuals to determine a machine's normal operating characteristics.
13. Using a manual, identify operational/functional systems.

Enabling Competencies

1. Recognize a mechanical problem which may, at first examination, appear to be an electrical one and vice versa.
2. Exhibit proper working habits (attitude and safety).
3. Interpret drawings of parts.
4. Interpret graphs and charts.
5. Read and use acceptable twelfth-grade English.
6. Perform trigonometric calculations.
7. Explain the difference between accuracy, precision, and repeatability.
8. Explain the difference between direct and indirect measurements.
9. Communicate
   a. Orally
   b. Listening
   c. Reading
   d. Write technical reports
   e. Graphically

Factory Processes

Enabling Competencies

1. Describe the following operations performed on a lathe:
   a. Plane or straight turning
   b. Facing
   c. Parting
   d. Chamfering
2. List common lathe accessories and attachments.
3. Identify important features of a horizontal turret lathe.
4. Describe a screw machine and the types of jobs accomplished on it.
5. Define an electron beam and how it is used as a special cutting tool.
6. Identify the machines and tools used for:
   a. Stamping
   b. Piercing
   c. Bending
   d. Drawing
   e. Rolling
7. Describe/list the cutting tools normally used on:
   a. Mills
   b. Lathes
   c. Drill presses
8. Describe painting processes.
9. Define and give an example of the following measurement terms:
   a. Tolerance
   b. Allowance
   c. Clearance
   d. Basic size
   e. Standard size
   f. Nominal size
10. Describe the differences between MIG, TIG and stick arc welders.
11. Describe gas welding equipment.
12. Explain flow and dip coating.
13. Describe anodizing.
14. Describe electroplating equipment and explain the process.
15. Describe aerobic and anaerobic adhesives.
16. Explain the difference between thermoset and thermoplastic plastics.
17. Describe injection molding.
18. Describe vacuum forming.
19. Compare similarities and differences of ECM and EDM.
20. List important factors that control the quality of surface finish obtained by ultrasonic machining.

Automated Systems

Terminal Competencies

1. Measure robot performance (distance, positioning, accuracy, and repeatability).

2. Use teaching pendant for testing, editing, and setup.
3. Disassemble, repair, test and return to service robots that have failed.
4. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots.
   b. End effectors
   c. Smart Actuators
5. Coordinate the operation of several pieces of automatic equipment.
6. Adjust feedback loops that include:
   a. Encoders/decoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessor
   e. Count stepper-motor pulses
   f. Optoelectronics
   g. Hall-effect devices
   h. Velocity sensors
   i. Position detectors
7. Interconnect robots and other equipment.
8. Adjust machines for accuracy and repeatability.
9. Set up machine vision systems.
10. Match off-the-shelf end effectors to the requirements of various manufacturing operations.
11. Analyze robot task requirements of a manufacturing operation.
12. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
13. Start-up and debug a robot system.
14. Start-up and shut down an automated production system.
15. Specify safety considerations for personnel, work area, operations, and maintenance.
16. Test wiring of each subassembly of a robot; test the overall, connected wiring of the total robot.
17. Install a programmable controller and its input/output devices.
18. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate, and repair a robot/automated system.
19. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.
20. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
21. Perform electrical adjustments on servo power amplifiers.
22. Perform zeroing of encoders.
23. Specify the robot coordinate system.
24. Develop material handling specifications for a work cell.
25. Specify the robot-to-material interfaces.
26. Define the human interface with a robot.
27. Define axis control and feedback specifications.
28. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot, and at least one machining center.
29. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.

30. Given the above setups, the instructor will install a programming error. The student (team) will diagnose and correct the problem and test the solution.
    a. Programming
    b. Mechanical stops
    c. Electrical
    d. Hydraulic power supply
31. Set up a robot to either paint parts on a moving line or weld parts on a moving line (line will stop for welding cycle).
32. Set up, etc. a robot to assemble two parts--use at least three fasteners:
    a. Index
    b. RCC
    c. Pickup
    d. Fasteners
    e. Install parts
33. Configure a system for counting regular/irregular-shaped objects moving on an overhead track.
34. Define signal-sensing-control and power interfaces involved in the first two problems.
35. Operate the following equipment
    a. End effectors
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices
36. Adapt the following to robotic application:
    a. Welder
    b. Adhesive applicators
    c. Paint sprayers
    d. Grinders
37. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders
38. Set up, operate, troubleshoot, and repair automated:
    a. Warehousing systems
    b. Machinery operations
    c. Coating/application systems
    d. Assembling stations
    e. Material-handling systems
39. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.

Enabling Competencies

1. Identify major systems of a robot.
2. Describe robot drive system operation.
3. Describe operation of various types of industrial robots.
4. Describe mobility of an industrial robot.
5. Describe transmission operation.
    a. Gears
    b. Pulleys, belts
    c. Bearings

6. Identify a robot's work envelope.
7. Be conversant in robot terminology.
8. Demonstrate knowledge of safety requirement for working around robots.

Design

Terminal Competencies

1. Create two-dimensional drawings using the graphics terminal, digitizer, and plotter as design and drafting tools.
2. Sketch views not shown on a drawing.

Enabling Competencies

1. Explain the hazard of accumulated tolerances (on a drawing).
2. Determine critical dimensions.
3. Describe the meaning of dimensions/tolerances shown on drawings.
4. Identify the components of a computer-aided drafting system.
5. Determine interrelationships of working dimensions.
6. Determine critical dimensions.

CHAPTER IV: STRUCTURE AND CONTENT OF THE ROBOTICS/AUTOMATED SYSTEMS CURRICULUM

This chapter of the guide describes the rationale, structure, and content of a recommended Robotics/Automated Systems Technician training program. The core curriculum approach is explained and the national model for a RAST curriculum is fully described. Course descriptions, outlines, and a suggested sequence are included.

Postsecondary technical institutes and community colleges are attempting to provide qualified technicians for computerized, automated production. To properly serve the students and their future employers, RAST programs must address two key questions:

- Does the program provide the broad knowledge and skills required by industry?
- Are the students adequately prepared to be retrained as technologies advance throughout their careers?

Advanced-level manufacturing technicians can be prepared by schools if curricula are designed with these two questions in mind. The curricula should first be broad based--include in the course/lab activities elements of several fields of study such as mechanics, electricity, electronics, pneumatics and hydraulics. Second, courses should progress from teaching basic fundamentals that apply to several areas of study to specialty application of specific disciplines.

A curricula so designed will satisfy two requirements of employers. First, new employees will have the broad-based training that facilitates retraining as needed; they will also be versatile--easily transferred from one assignment to another. The second employer requirement is to establish retraining programs for current craft and assembly workers. Schools that have well designed curricula in the advanced technologies will be able to customize a program to fit a specific manufacturer's needs.

The previously referenced Advanced-Technology Core Curriculum Guide describes in detail the broad-based, multidisciplinary approach to technician education. It provides a comprehensive analysis of the differences between a two-year, high-technology technician preparation program and the traditional "single-discipline" programs. The philosophy, structure and administrative advantages of the core curriculum approach are explained. The core guide is recommended as a fundamental background document for those involved in implementing Robotics/Automated Systems Technician training programs or other advanced-technology programs. A brief summary of the core curriculum approach is provided in this section of the guide.

THE CORE CURRICULUM

The core curriculum model designed by CORD provides for a broad technical base with more emphasis on scientific principles underlying the function and design of devices and systems. The core curriculum is comprised of two main parts:

- The basic skills area--including the major underlying science of the technology and the supporting mathematics, communication skills, computer literacy, and industrial relations or other socio-economic subjects.
- The second part of the core curriculum is the area known as the technical core--including courses in the various technical disciplines: electricity and electronics, mechanics, fluids (hydraulics and pneumatics), material properties, computers, controllers, thermics, and graphics.

These two areas provide general career preparation and the necessary foundation for technical specialization in a range of advanced-technology programs such as robotics, lasers, telecommunications, instrumentation and controls, etcetera. Specifically, these two areas support the tasks that RASTs are expected to perform. Course descriptions for basic skills and technical core courses follow the graphic model of the RAST curriculum shown in Figure 4.

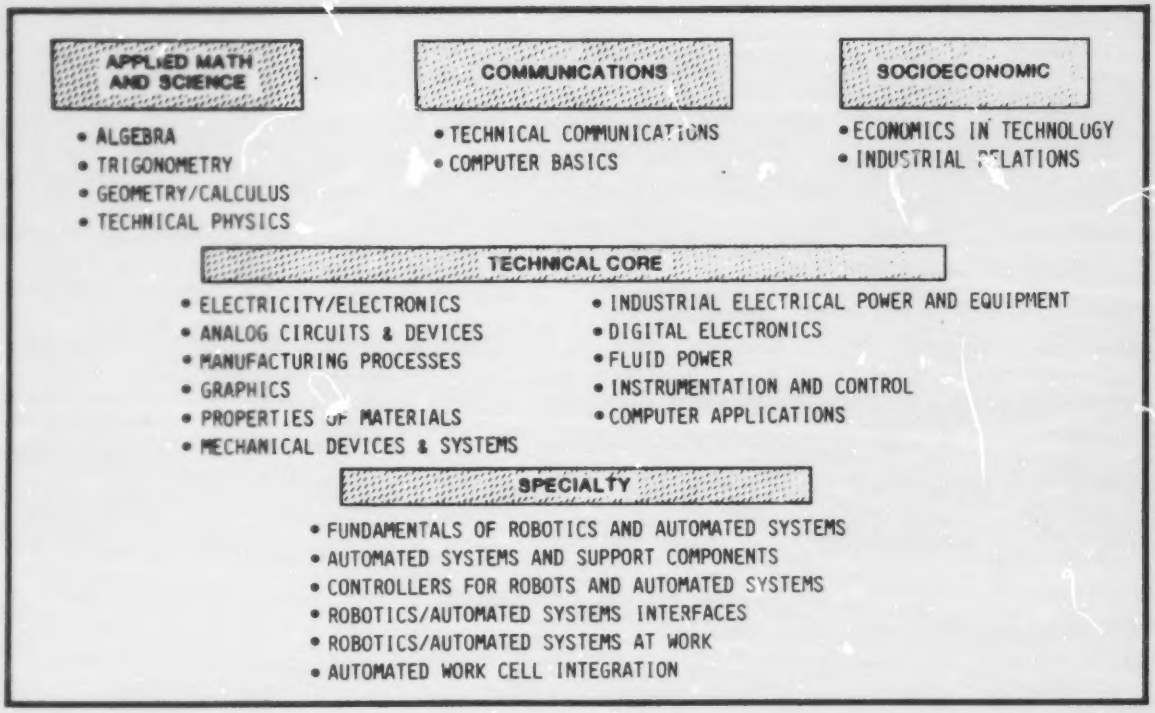

Fig. 4 Robotics/Automated Systems Technician curriculum model.

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BASIC SKILLS COURSE DESCRIPTIONS

ALGEBRA

This course is designed to develop and update algebraic skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic and optical technologies. Topics to be covered include functions and graphs, exponents, radicals, linear equations, determinants, factoring, quadratics, and various techniques for solutions of equations and systems of equations.

TRIGONOMETRY

This course is designed to develop trigonometric skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic and optical technologies. Topics to be covered include trigonometric functions of angles, vectors, solutions to oblique triangles, graphs of trigonometric functions, j-operators, inverse functions and logarithms.

ANALYTIC GEOMETRY AND CALCULUS

This course is designed to develop analytic geometry and calculus skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic, and optical technologies.

UTC PHYSICS I

A practical approach to the teaching of basic physics of force, work, rate, momentum, and resistance is presented in Physics I. Students are shown, by classroom demonstration, how these five concepts are applied to the four energy systems--mechanical, fluid, electrical, and thermal. Students perform laboratory experiments that relate each concept to the four energy systems.

UTC PHYSICS II

The second quarter of Physics builds on the foundation developed in the first quarter by presenting concepts of power, energy, force transformers, and energy convertors. Appropriate laboratories provide practical hands-on experience in working with associated devices in the four energy systems (mechanical, fluid, electrical and thermal).

UTC PHYSICS III

The third quarter of Physics provides the student with practical knowledge of scientific principles involved in transducers, vibrations and waves, time constants, and radiation. Practical hands-on experience with devices common to many technologies is offered in the laboratory.

TECHNICAL COMMUNICATIONS

Technical Communications provides the student with a working knowledge of communication techniques, procedures, and formats used in industry and business. The student learns accepted methods of describing devices and processes; of making oral and written technical presentations; maintaining a laboratory notebook; and of using written manuals, guides, specifications and vendor instructions. Most importantly, the student is involved extensively in writing various technical reports and in preparing/delivering appropriate technical presentations.

COMPUTER BASICS

This course will provide students with knowledge and skills, to use the microcomputer as a tool to solve engineering technology problems typically encountered throughout their programs. Topics taught will include microcomputer architecture, programming concepts, branching, looping, arrays, functions, subroutines, data files, graphics and applications.

ECONOMICS IN TECHNOLOGY

Economics in Technology develops the techniques necessary to evaluate the economic impact and advantages of different production methods. It is a course designed to familiarize the student with analysis techniques that are necessary for accurate cost evaluation of specific projects. The conceptual format enables the student to apply appropriate tools to a diversity of cost-related decisions.

INDUSTRIAL RELATIONS

This course includes the study of the basis of human relations and the organization of individual and group behavior. Leadership, organizational and social environments (including labor unions), career development, communications and group processes as well as selected operating activities are covered. Appropriate case problems are reviewed and discussed. Special emphasis is placed on typical industrial and business relationships in everyday situations.

TECHNICAL CORE COURSES

FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS

This course provides the foundation for the principles of electricity and magnetism required for further study in electricity and electronics. Topics discussed include basics of electricity and magnetism, electrical charge in motion, dc circuit analysis, ac circuit analysis, magnetic circuits and devices, reactance, and impedance.

DIGITAL ELECTRONICS

This course will present the student with common digital circuits such as multivibrators, counters, shift registers and memories. Students will examine and work with bus structures, data transmission techniques, and interfacing.

ANALOG CIRCUITS AND ACTIVE DEVICES

This course will expose the student to the most common circuit applications for analog devices. Amplifiers, oscillators and other circuits employed in industrial measurements and control are examined as well as the theory of operation behind AM, FM and SSB.

ELECTROMECHANICAL DEVICES

Electromechanical Devices provides the student with a working knowledge of control elements in electrical circuits, transformers, motors and generators. Topics presented include switches, circuit breakers, relays, fuses, transformers, dc and ac motors and generators.

GRAPHICS

An introductory course that provides the technician with basic skills and techniques used to communicate information and ideas graphically. Topics include: an introduction to freehand sketching; basic drafting techniques and procedures; schematic drawing; descriptive geometry; and computer graphics.

PROPERTIES OF MATERIALS

A quantitative survey and description of the physical, chemical, mechanical, thermal, electrical, magnetic, acoustical and optical properties of materials. The course identifies and uses resource tables and handbooks extensively. Laboratory exercises provide the student with a broad exposure to the measurement of typical material properties.

MECHANICAL DEVICES AND SYSTEMS

Mechanical Devices and Systems is a study of the principles, concepts, and applications of various mechanisms encountered in industrial applications of engineering technology. Such mechanisms include belt drives, chain drives, linkages, valves, fans and blowers. The subject matter on mechanical components and systems covers operational principles, uses, maintenance, troubleshooting, and procedures for repair and replacement. The laboratory applications emphasize practical maintenance and installation of equipment and selection and specification of proper replacement components from manufacturers' catalogs.

FLUID POWER

The course in Fluid Power is designed to provide the student with an overview of fluid power technology and a working knowledge of each of the components used in fluid power circuits. Hydraulic and pneumatic systems will be discussed. Topics presented will include fundamentals of fluid dynamics, conventional fluid circuits and fluid power components.

INSTRUMENTATION AND CONTROLS

Instrumentation and Controls is designed to provide the student with practical knowledge and skills in the specification, use and calibration of measuring devices and the principles and applications of automatic control processes for electrical power production, heating, air conditioning and manufacturing.

COMPUTER APPLICATIONS

This course provides an introduction to the hardware and software architecture of microprocessor systems used in applications of signal processing and control. Specifically, the course covers techniques for processing both analog and digital information into and out of microcomputers and applies these techniques to real-world control problems.

INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT

This course deals with the source, distribution, and use of electrical power in industrial plants. The first part of the course describes ac electrical power as it arrives at the plant substation and the electrical equipment needed to transform it to useful voltages, distribute it effectively and protect it from overcurrent conditions. Equipment typically includes transformers, switchgear, fuses and relays. The second part of the course deals with electromechanical equipment required to convert electrical power into useful, rotational mechanical energy. Equipment typically includes ac and dc motors, motor controllers and synchromechanisms.

MANUFACTURING PROCESSES

This course provides a background in manufacturing materials and manufacturing methods employed in cold working processes. Through lecture, demonstration, and practical applications the student becomes familiar with various types of machine tools, tooling, measuring, and inspection procedures. Automation and numerical control for machine tools are introduced.

One key to the success of the core curriculum is the way in which underlying scientific principles are taught. Unified Technical Concepts (UTC) is the applied physics course recommended for the core curriculum. UTC physics teaches the methods of energy transfer between systems. The systems studied are identified as mechanical, electrical, thermal and fluid. Equivalent or similar concepts between the systems, such as force or work, in each system are demonstrated so that students gain an understanding of these similarities. A more complete description of UTC Physics is found in Appendix C.

SPECIALTY COURSES

The third portion of the curriculum is composed of the specialty courses. These are the systems courses in which students assemble and

disassemble operational automated systems. The laboratory courses include troubleshooting, repair, calibration, and maintenance of automated systems. The descriptions of specialty courses below are followed by a suggested course sequence chart based upon a quarter system, and a quarter-by-quarter course flow chart. A full description of the specialty courses including a course outline, laboratory activities and competencies is included in Appendix B.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

This course introduces the student to robotics and automated systems and their operating characteristics. Topics to be covered include robotics principles of operation and work envelopes. Students will learn the various coordinate systems and how hydraulic, pneumatic and electromechanical systems function together as a system. Other subjects to be covered include servo and nonservo controls, system capabilities and limitations, and safety. Robot tooling will be investigated including welders, grippers, magnetic pickups, vacuum pickups, compliance devices, adhesive applicators, and paint sprayers.

CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS

Students will learn the principles of control systems and how they are applied to a production system to achieve automation. Systems included in the course are drum controllers, stepper motors, programmable logic controllers, microprocessors, computers, feedback systems and robot controllers.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

Students learn the concepts of production--mass production, batch processing, and job shopping. They also learn how identical support components are applied to different types of automated manufacturing. Proper orientation of parts will be examined in the laboratory. Also, sensor performance will be compared to manufacturer's data.

ROBOTICS AND AUTOMATED SYSTEMS INTERFACES

Students in this course will learn the principles of interconnecting (interfacing) controllers, sensors, and actuators. They will study, set up and operate simple (discrete, binary) and complex (analog) sensors, tooling, controllers and network interfacing.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

This course provides students an opportunity to observe and study the application of robots and automated systems to manufacturing. Students will simulate in the lab several of the systems observed in industry. The laboratory exercises are aimed at evaluating current systems and attempting to improve them.

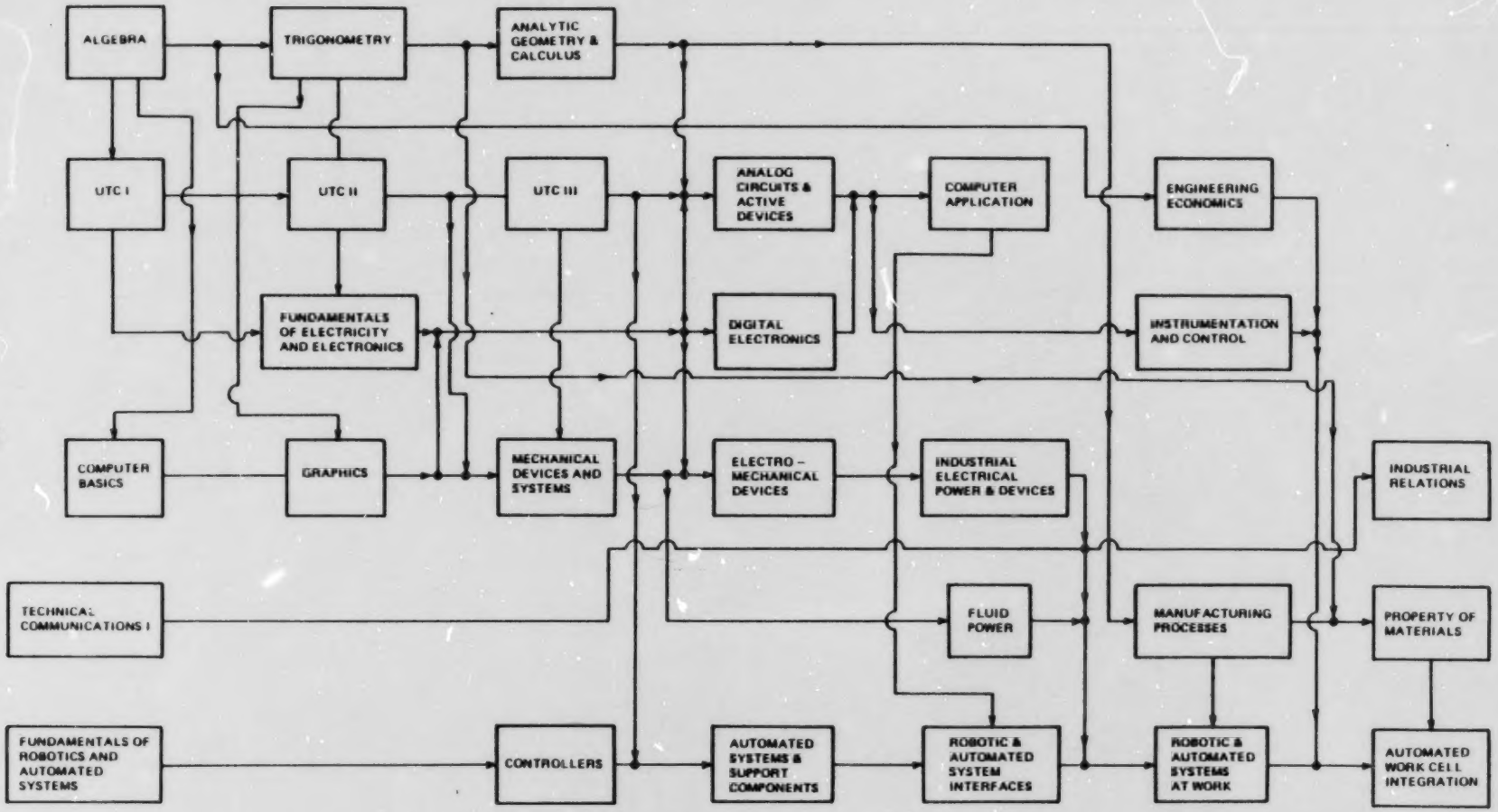
AUTOMATED WORK CELL INTEGRATION

Students, working in teams and under the instructor's supervision, will assemble and operate an automated production system. The students will select equipment, write specifications, design fixtures and interconnects, integrate system/provide interfaces, and make the assigned system operational. This is a laboratory class.

COURSE SEQUENCING CHART
Robotics/Automated Systems
Suggested Program (Quarter System)

	Lecture	Lab	Weekly Contact Hours
First Quarter			
Algebra	3	2	5
UTC Physics I	3	6	9
Technical Communications	3	2	5
Computer Basics	2	4	6
Fundamentals of Robotics & Automated Systems	2	3	5
	13	17	30
Second Quarter			
Trigonometry	3	2	5
UTC Physics II	3	6	9
Fundamentals of Electricity & Electronics	3	4	7
Graphics	1	6	7
	10	18	28
Third Quarter			
Analytic Geometry & Calculus	3	2	5
UTC Physics III	3	6	9
Controllers for Robots & Automated Systems	2	6	8
Mechanical Devices and Systems	2	4	6
	10	18	28
Fourth Quarter			
Analog Circuits & Active Devices	3	4	7
Digital Electronics	2	4	6
Electromechanical Devices	3	4	7
Automated Systems & Support Components	2	6	8
	10	18	28
Fifth Quarter			
Industrial Electrical Power & Equipment	3	4	7
Computer Applications	3	4	7
Fluid Power	3	4	7
Robotics & Automated Systems Interfaces	2	6	8
	11	18	29
Sixth Quarter			
Instrumentation & Controls	2	4	6
Economics in Technology	4	0	4
Manufacturing Processes	4	3	7
Robotics/Automated Systems at Work	2	6	8
	12	13	25
Seventh Quarter			
Properties of Materials	2	4	6
Industrial Relations	5	0	5
Automated Work Cell Integration	2	6	8
	9	10	19

ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN COURSE FLOW CHART



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CHAPTER V: PROGRAM PLANNING AND IMPLEMENTATION

This chapter of the guide contains recommendations and information regarding the planning and implementation of a Robotics/Automated Systems Technology curriculum. The overview of the initial planning process has been kept brief, as this process is covered in detail in the Advanced-Technology Core Curriculum Guide. The process explained in Chapter III of the core guide, "Program Planning," applies to the initiation of RAST programs as well as to other advanced-technology programs. The main part of this chapter is devoted to the many logistical considerations involved in implementation of a new curriculum: facilities and equipment, staffing, costs, and entrance guidelines, to name a few.

OVERVIEW OF PLANNING PROCESS

When initiation of a RAST program is under consideration, the postsecondary institution must begin with a process of investigation and assessment. Information must be gathered from staff, governing boards, employers, state and local agencies, existing programs, and state and local industries. It should be understood at the outset, however, that to make a study of a potential new program does not necessarily result in program implementation.

The chief administrative officer of the school and/or dean of program development or instruction usually provides the leadership for the investigative process through which the feasibility of a potential RAST program is examined. Often a task force of administrators and instructors is formed to carry out the work of gathering and organizing information. Usually they work with an ad hoc committee of employers and other advisors who provide valuable direction and information. The planning process is described in detail in the Advanced-Technology Core Curriculum Guide; it can be seen as involving six basic steps:

1. Form an ongoing advisory committee.
2. Conduct feasibility and verification meetings.
3. Assess occupational changes brought about by robotics/automated systems technology.
4. Perform inventory of and/or list tasks required.
5. Adapt model curriculum.
6. Propose program to governing agency.

Formation of the Advisory Committee

The key to an effective RAST program is maintaining meaningful contact with employers who will eventually hire the program's graduates. The ongoing advisory committee members should be appointed by the school's chief

administrator--usually for two- to three-year staggered terms. In some cases, the ad hoc committee members will want to make a longer commitment to work on the school program; other ad hoc members may suggest alternate appointees for the ongoing advisory committee. The functions of advisory committees are discussed at greater length in the core guide.

Feasibility and Verification Meetings

The advisory committee's first task is to examine a candidate curriculum, and offer constructive criticism and suggestions for revision. After revision has been carried out, the advisory committee should meet to verify the curriculum that is to be implemented.

Assessment

The next step of assessment is begun when the task force is formed and they, in turn, convene an ad hoc advisory group. The ad hoc advisory group usually consists of local high-tech industry representatives (first-line supervisors, representatives from scientific and technical societies and other technical advisors). Together, these groups assess changes in workplace equipment, skill requirements and workforce needs. They must make local determinations of: the job opportunities for technicians and their growth potential; the tasks and competencies needed locally that may be different from, or in addition to, the general task list; specific equipment and high-technology apparatus being used by RASTs or closely related workers in local industries; required laboratory and classroom facilities to support the program; and availability of qualified instructors. The group also must determine the attitude of local employers toward upgrading and updating of their employees to meet advancing-technology requirements, and their visions of entering or expanding new high-technology initiatives in their industries.

Task Inventory

As the work of assessment proceeds, it must become more specific. A refined task and competency list based on local and regional industry performance requirements should be developed. The national task list developed by CORD and included in Chapter III of this guide is a good starting place for the local list. Members of the ad hoc robotics/automated systems industry advisory committee can review the national task list, suggest other needed tasks and competencies, and perhaps delete from the national list according to local job needs.

Construct a Curriculum for the Program

With clear evidence that more robotics/automated systems technicians are needed by local employers and a detailed list compiled by local industry advisors describing the competencies and activities the technicians must be able to perform, the basic information is available for the program task force to take the next major step: prepare a curriculum for the new program.

Probably the most practical way to construct a curriculum for the new program is to start with an existing up-to-date model curriculum for RASTs. The content of each course in the model curriculum should be analyzed in detail as it relates to the task and competency list, and modification should be made in the courses and their content to clearly reflect current local industrial needs. The resulting curriculum then should be reviewed and approved by the industrial advisory committee.

Program Proposal

In most institutions, a formal proposal for program implementation must be prepared and sent to administrators, boards and agencies. Such a proposal should address three criteria:

- Need for a program.
- Capability of institution to provide the program.
- Cost effectiveness.

The proposal is discussed at greater length in the Advanced-Technology Core Curriculum Guide.

STEPS TO IMPLEMENTATION

When the initiation of a new RAST program is approved, there are critical steps that must follow, several of which must be accomplished concurrently. Most of these steps are not new to experienced technical education administrators and so are not elaborated upon to any great degree. The following steps usually are needed in initiating a program after its approval.

1. Prepare a tentative month-by-month schedule of preparatory tasks that must be accomplished before the new program begins.
2. Employ and orient a qualified person to be the department head for the new program.
3. Redirect the staff program assessment committee and the industrial advisory committee to perform the program development tasks leading up to the beginning of the program. (It is most important that the department head and industrial advisory committee leaders and members form a working relationship based on mutual respect and interdependence. They can accomplish the best programmatic results as a close-knit team working toward the objective of providing highly qualified technicians to the local industries.)

4. Prepare materials to announce and publicize the RAST program and to attract students to the program.
5. Refine plans for and design of the physical facilities, the identification, acquisition and installation of laboratory equipment, library content (see Appendix D for references and periodicals) and supplies needed to start the program.
6. Review and refine the details of the curriculum, establishing the course titles, materials to be used, staff required and teaching staff relationships under the core curriculum plan.
7. Employ required additional instructional staff to teach technical specialty classes and laboratory units and the basic and technical core learning experience portions of the curriculum.
8. Orient and prepare the total instructional staff involved in the program so they will understand the program and function as a team.
9. Initiate the program.
10. Evaluate and revise the program as needed. After the first term of operation or at any time even prior to that or subsequent to it, student progress, staff attitude and performance should be evaluated so that changes can be made if necessary.

INSTRUCTIONAL METHODOLOGY

The instructional materials that have been developed for this program place heavy emphasis on the practical--not the theoretical. Even in a technology as sophisticated as robotics and automated systems, it is not only possible, but necessary, to teach technicians the methods and techniques instead of theories and derivations of formulas. This emphasis on learning objectives should be conveyed by the RAST instructor as well as in the texts.

As a consequence of the emphasis upon principles, skills, methods and techniques, the suggested primary method of instruction is laboratory-centered learning, that is, "learning by doing." The instructional materials for robotics/automated systems technology are being developed and tested at the technician level. They are being approved by industrial representatives who actually hire RASTs. The instructional modules contain performance objectives, the discussion, and laboratory activities that exemplify the principles outlined in the discussion.

Benefits to be gained through performance objective analysis make the effort worthwhile. This type of analysis makes possible an exact specification of the demands of each entry-level job, and of the training paths necessary for the student to qualify as a robotics/automated systems technician, or as a worker in a related field.

A faculty coordinator should be selected and briefed about the RAST program. The faculty coordinator should be capable of bringing together existing faculty members as a cohesive working group so that courses will be taught as bridges to one another, rather than as unconnected islands of

subject matter. The interests and capabilities of faculty members must extend beyond their specialties, or the spirit that attracts and draws out highly motivated students will be lost.

Teaching materials--including auxiliary aids, texts and references--must be kept up-to-date with developments in the field, and with research in support areas and communications skills. Instructors should make a practice of reviewing new texts and other teaching materials as they appear, with regard to both content and methods. The list of suggested texts and other teaching materials that has been included in this guide (Appendix D) is not all-inclusive, as new texts are constantly being published.

STAFFING

Competence and enthusiasm of the teaching staff are major factors in the success of an RAST program. Ease in handling technical subject matter and understanding the problems of industry is at least as important as teaching experience. Technical education is unique in its integrated theoretical and practical approach. The teaching staff should be aware of this.

Each faculty member should be familiar with the full range of skills and knowledge that a RAST is expected to have at his or her disposal. For instance, an electronics teacher who is familiar with the program's communications skills requirements will be able to exemplify them in oral and written presentations.

When a faculty coordinator has been chosen, staff selection begins with the identification of applicants who have skills in manufacturing, hydraulics, mechanics, electronics and instrumentation. Ideally, at least one member of the RAST faculty should have worked in a robotics or a manufacturing industry or laboratory for at least three years. However, persons with this type of experience are earning very high wages and it is a rare experience to find one with enough commitment to technical education to leave his or her profession to enter teaching. If a faculty member with the requisite experience in robotics and automated systems cannot be obtained, it is suggested that existing faculty members in electronics or physics be employed on the RAST staff and that practicing engineers or physicists be used to teach on a part-time basis.

Potential faculty members should be aware of all the advantages to the program of having strong industrial ties. Ability to work with others is very important, as it guarantees a sense of continuity as students move from course to course. The model program has been designed for successful implementation with minimal faculty coordination, but without it, there is less probability of maintaining student motivation and enthusiasm; and these qualities are very important to potential employers.

Course loads of from 18 to 25 contact hours per week will permit faculty members to maintain and update their technical capabilities, which is extremely vital in this rapidly developing and changing technology. It is suggested that faculty members make frequent visits to industrial sites and take one-quarter sabbaticals every two years for the specific purpose of working in robotics or manufacturing industries. Some funds for travel and study and allocations for time off will be necessary if this is to be accomplished.

Staff orientation can be carried out within the institution, or in cooperation with other schools. Professional societies and organizations such as CORD can help institutions prepare and implement in-house faculty training programs.

FACILITIES

Facilities required for RAST programs include classrooms, laboratories, staff offices, a student lounge area, and library facilities. The following description is based on classes of sixteen students each, scheduled to allow for handling of up to three laboratory sections weekly for each class.

A high ratio of laboratory to classroom space is recommended, because the greatest amount of learning takes place in the laboratory where students have the opportunity to operate and work on and with real equipment. Facilities requirements for core curriculum courses are included in the core curriculum guide.

No unusual utility services are required in RAST classrooms. Duplex outlets should be provided for use of audiovisual aids and demonstration equipment. Service requirement need not exceed 30 amperes at 110 volts, 60 hertz. Minimum classroom lighting level should be 70 footcandles.

Staff office space should allow for about 100 square feet per teaching faculty member. There should be a limit of one person to an office so that counseling does not become awkward for the teacher or embarrassing to a student. Normally, several faculty members can share one secretary who will provide clerical, appointment and coordination services.

Laboratory requirements given here allow for implementation of the full RAST program, but individual institutions may start up their RAST laboratory facilities as adjuncts to existing electronics, manufacturing or physics laboratories.

CORD recommends, for a fully implemented program, about 80 square feet of laboratory space for each student. The laboratories should be windowless, painted a flat, light blue, and well lighted. Lighting level should be between 70 and 100 footcandles.

Each laboratory should be equipped with safety lights, door interlocks and intrusion-control locks to ensure protection of students, faculty and visitors. Arrangement of the total laboratory area should permit easy access for visitors, but should also prevent interference by them with student work and with equipment. There should be an easily accessible storage and control space for safety glasses near at least one entry point.

EQUIPMENT

Equipping the laboratories presents a tremendous challenge to faculty and administrators. The planning for this task is really part of an ongoing project that must be started early in the curriculum design process by collecting catalog information describing robots and ancillary equipment. One faculty member should have his or her name placed on the mailing lists of four or five trade publications, such as Machine Design and Design News. Also important is joining a professional society such as Robotics International of the Society of Manufacturing Engineers.

Reading these magazines not only provides information on the latest advances in technology, but provides a source of catalog data. Almost all journals and magazines have return-mail postcards. These should be used to build a catalog file that will provide research data when it's time to purchase equipment.

The local advisory committee should also be utilized in defining laboratory equipment to be purchased. Appropriate robots and support systems should be purchased to equip work cells for three to five of the following applications.

1. Pick and place
2. Resistance welding
3. Materials handling
4. Machine loading/unloading
5. MIG welding
6. Spray painting
7. Application of glues and sealants
8. Assembly
9. Inspection
10. Remote handling of hazardous materials
11. Agricultural applications
12. Biomedical applications

EVALUATION

The individuals responsible for the planning, development and implementation of a RAST program should feel accountable to students, industry and

the educational institution for a high-quality program that will train men and women for useful work. Training evaluation involves quality-control procedures for, and is an integral function of, training development, modification, revision and improvement. Continuous evaluation of the program is necessary to ensure that project objectives are accomplished. It includes a systematic procedure and checkpoints to ensure relevancy, appropriateness, substance and teaching effectiveness.

The final evaluation of a technology program is the graduate's success at finding one or more jobs that have advancement opportunities--and, given this, the employer's satisfaction with technical and social abilities of the employee. All other evaluation criteria fall into line behind these two.

It would certainly be unwise for administrators of a RAST program to put off judging its effectiveness until the first two-year course was completed. Accordingly, especially for the new program, "input" and "process" evaluations are equally as important as "output" measures. Input evaluation can be performed by measuring program elements against industrial needs. Process evaluation allows faculty and staff to do everything they can to improve the program even as it is being taught for the first time.

Three elements of process evaluation are analysis of the:

- Objectives--are they consonant with industrial needs at each step of the way?
- Curriculum Materials and Equipment--are they supportive and relevant to accomplishing the objectives?
- Instructional Methods--are they efficient in developing students' knowledge and skills?

Feedback information should be gathered from all available sources throughout planning, implementation and placement. Every participant--students, faculty, staff and advisory personnel--should be involved in the evaluation process. Another evaluation technique, which may be a part of a regular follow-up system, is a periodic review of the program by employed graduates. Such a review provides positive feedback by relating program content to occupational needs. Feedback from graduates is especially valuable in making program changes that incorporate new technological developments.

ANALYSIS OF COSTS AND FUNDING FOR THE PROGRAM

Data developed in the preceding items of this section contain basic elements of the costs that will be incurred in initiating and operating the new robotics/automated systems program, assuming first-year classes of 30 to 35 students and a second-year class of 20 to 25 students. Major items to be considered are staffing, equipment and facilities.

A detailed summary should be made of new capital costs required to start the program and the costs of additional required staff and overhead. These should then be projected for the first, second and succeeding years as total estimated annual operating costs of the program. Facility and equipment costs should be determined for technical specialty (RAST) courses and for the common core basic courses such as physics, graphics and computers. An assessment of potential funding to meet the cost of initiating and operating the new program also must be made to provide a clear picture of the financing needs for the new program.

PROGRAM ALTERNATIVES TO REDUCE COST

In certain cases the total cost of the RAST program, using the suggested model facilities and equipment described in this guide, may seem prohibitive. Some suggestions for reducing costs are presented below. The ideas have been tried and proven in several institutions. The ingenuity of local institutional planners and faculty will no doubt suggest others.

1. Individualized instruction and open labs: Use of open labs can help reduce costs by decreasing the number of laboratory setups needed for a single demonstration. In this regard it should be mentioned that the number of capital and noncapital items listed for each course in the equipment list is based upon a class of 20. Ideally, two-person lab teams should be used (that is, lab setups per experiment for one lab section). Thus, if only eight students are anticipated for a given course, the number of lab setups can be decreased by half, and so forth.
2. In-house equipment fabrication: The technical members of the industrial advisory committee can frequently be of immense help in designing equipment for student projects, and in arranging equipment loans or donations of (used) equipment. Much useful equipment can be obtained at minimal cost (often just transportation costs) through state and federal surplus property agencies, and through used equipment grant programs available in governmental agencies. It is important for the institution, if possible, to have one person whose assignment is to be aware of and seek out sources of surplus and excess property.
3. Use of student aides: Instead of hiring two instructors initially to implement the RAST program or option plan, one instructor can be used if he or she has the help of work/study students and lab assistants.
4. Library facilities: Books, journals and films for the RAST program (see Appendix D) may be acquired gradually. The references listed at the end of each module serve as a guide for planning library acquisitions for each course. Cooperative arrangements can sometimes be worked out with nearby engineering libraries, also.
5. Where a full RAST specialty sequence cannot be implemented for financial reasons, institutions may find it feasible to offer single courses in specific robotics skills for currently employed but inadequately trained technicians. Such courses can successfully demonstrate the capability of the institution to offer relevant training and may form the basis for a full-scale program implemented with industry cooperation at a later date.

APPENDIX A

ROBOTICS/AUTOMATED SYSTEMS SURVEY QUESTIONNAIRE

Robotics/Automated Systems Technicians (RAST) are technical specialists with broad-based electromechanical skills who are familiar with electronic, mechanical, hydraulic and pneumatic devices. They are usually specialists in robotics or processing equipment and can set up automatic machines that work together as part of a total automated system. In their area of specialization, they can install, set up, troubleshoot, integrate, program, modify, test, operate and repair systems and components. They are field-service, installation or service technicians. They will work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

1. Do you have any RASTs employed at your company?.
   _____ Yes _____ No
2. Please indicate the approximate number of RASTs employed at your company. _____
3. Please give your best estimate of the expected number of RASTs to be employed by your company.
   _____ for the year ____ (two years from now).
   _____ for the year ____ (six years from now).

If your answer for questions 1, 2, and 3 is none, go to question 8.

4. Please indicate the average starting salary for a RAST per year.
   _____ (a) below $10,000
   _____ (b) $10,000--below $15,000
   _____ (c) $15,000--below $20,000
   _____ (d) over $20,000

5. Please indicate those areas in which you think a RAST should receive specialty training.

_____ Computer hardware
_____ Computer software
_____ Conventional optics (geometrical and wave optics)
_____ Electronics
_____ Electro-optical devices
_____ Fiber optics
_____ Hydraulics
_____ Industrial electricity
_____ Lasers
_____ Management
_____ Manufacturing processes
_____ Pneumatics
_____ Programming
_____ Report writing
_____ Safety and OSHA
_____ Sales methods and techniques
_____ Other (please specify) _____

_____

6. Please give your name and the name and address of your firm.

_____

_____

_____

_____

Your kind assistance in completing and
returning this survey questionnaire is appreciated.

APPENDIX B

SPECIALTY COURSE OUTLINES

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

Classroom/Lab hrs/wk 2/3

COURSE DESCRIPTION

This course introduces the student to robotics and automated systems and their operating characteristics. Topics to be covered include robotics principles of operation and work envelopes. Students will learn the various coordinate systems and how hydraulic, pneumatic and electromechanical systems function together as a system. Other subjects to be covered include servo and nonservo controls, system capabilities and limitations, and safety. Robot tooling will be investigated including welders, grippers, magnetic pickups, vacuum pickups, compliance devices, adhesive applicators, and paint sprayers.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Introduction to Robotics and Automated Systems	2	3
A. Description of a System		
B. Definitions		
1. Robots		
2. Automation		
C. Elements of Automation		
1. CAD (CADD)		
2. CAM		
3. CAD/CAM		
4. CAE		
5. CIM		
D. Robot Components		
1. Manipulator		
2. Power supply		
3. Controller		
4. Transducers		
II. Robotics/Automated Systems Hazards and Safety Requirements	2	
A. Three Axioms		
B. Three Laws		
C. Robot Hazards (risk identification)		
D. Regulations		
1. NFPA		
2. OSHA		
3. NEMA		
4. JIC		
5. NMTBA		
6. IEEE		

		Student Contact Hours Class	Laboratory
	7. NEC		
	8. ANSI		
	E. Mental Attitude		
	1. Cleanliness		
	2. Neatness		
III.	Robotic Operating Parameters	4	6
	A. Interpreting Manufacturer's Specifications		
	1. Accuracy/repeatability		
	2. Coordinate system		
	3. Speed		
	4. Arm geometry		
	B. Degrees of Freedom		
	1. Definition		
	2. Robot/arm		
	3. Wrist/tool		
	C. Payload		
	1. Mass		
	2. Limitations		
	3. Radius (cg distance from mount surface)		
	4. Moment of inertia		
IV.	Robot Programming Characteristics	4	6
	A. Reference Planes of Motion		
	1. Tool control path		
	2. Robot's coordinate system		
	B. Programming Characteristics		
	1. Language		
	2. High/medium/low technology		
	C. Path Control		
	1. Point-to-point		
	2. Controlled path		
	3. Continuous path		
V.	Robot Structural Systems	2	3
	A. Mechanical		
	1. Support		
	2. Structural		
	3. Arm-motion control		
	B. End-of-Arm Tooling		
	1. Tooling		
	2. Compliance devices		
	3. Applications		
	C. Grippers		
	1. Parallel motion		
	2. Angular motion		
	3. Special		

	Student Contact Hours	
	Class	Laboratory
VI. Robot Drive Systems	2	6
A. Electrical		
1. Power		
2. Control		
3. Servo		
4. Stepper motors		
B. Hydraulic		
1. Pumps		
2. Actuators		
3. Valves		
C. Pneumatic		
1. Pumps		
2. Actuators		
3. Valves		
VII. Robot Control and Feedback Systems	4	6
A. Control		
1. Open loop		
2. Closed loop		
B. Transducers		
1. Discrete		
2. Analog		
C. Relative and Absolute Positioning		

STUDENT LABORATORIES

I. Measure Robot Physical Characteristics
Coordinate systems
Speed of operation
Payloads
Work envelope

II. Identify Robot's Path Control Characteristics and Reference Planes
Point-to-point
Control path
Continuous path

III. Program Robots and Automated Systems
Teach pendant
Lead through
Off line
Post processor

IV. Program/Operate End-of-Arm Tooling
Grippers
Vacuum pickups
Magnetic pickups

V. Describe and Operate Drive System
   Mechanical
   Electrical
   Hydraulic/pneumatic

VI. Identify Major Systems
   Mechanical
   Electrical
   Hydraulic
   Pneumatic
   Controls
   Sensors
   Servos/nonservos
   End-of-arm tooling

STUDENT COMPETENCIES

Upon completion of this course students will be able to:

1. Measure robot performance (distance, positioning, accuracy and repeatability).
2. Specify the robot coordinate system.
3. Operate the following equipment.
   a. End-of-arm tooling
   b. Grippers
   c. Magnetic pickups
   d. Vacuum pickups
   e. Compliance devices
4. Identify major systems of a robot.
5. Describe robot drive system operation.
6. Describe mobility of an industrial robot.
7. Identify a robot's work envelope.
8. Be conversant in robot technology.
9. Demonstrate knowledge of safety requirement for working around robots.
10. Specify safety considerations for personnel, work area, operations and machines.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students learn the concepts of production--mass production, batch processing, and job shopping. They also learn how identical support components are applied to different types of automated manufacturing. Proper orientation of parts will be examined in the laboratory. Also, sensor performance will be compared to manufacturer's data.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Types of Manufacturing	2	0
A. Mass Production		
1. Large volume		
2. Hard or fixed automation		
3. Single-purpose machines/transfer lines		
B. Batch Processing		
1. Small volumes		
2. Job shop		
3. Flexible automation		
4. Group technology		
C. Job Shopping		
1. Limited production		
2. Flexible manufacturing (if large or expensive items)		
II. Parts Movers	4	15
A. Parts Feeders		
1. Bowl feeders		
2. Hoppers		
3. Gravity feeders		
B. Material Handlers		
1. Conveyors		
2. Wire-guided vehicles		
3. Cranes		
4. Lift, carry, and shuttle-type transfer devices and systems		
5. Power-and-free versus synchronous		
6. Walking beams		
III. Jigs and Fixtures	4	12
A. Free-Effort Fixtures		
B. Parts Orientation		
C. Fixture Optimization		

		Student Contact Hours	
		Class	Laboratory
IV.	Positioners A. Electrical B. Pneumatic C. Hydraulic D. Index tables	4	15
V.	Sensors (Direct Reading/Discrete [Single-Function] Devices) A. Limit Switches B. Position Indicators C. Level Indicators D. Tactile E. Pressure F. Temperature	4	18

STUDENT LABORATORIES

I. Observe and Describe Three Types of Manufacturing
Take field trips and write reports describing observed manufacturing operations
Separate ten parts according to common manufacturing operations (Group Technology)

II. Set Up Part Feeders
Operate rotary hopper
Operate bowl feeders
Determine parts presentation requirements

III. Operate the Following Types of Material Handlers
- Conveyors
- Wire-guided vehicles
- Gravity feeders

IV. Evaluate the Following Types of Sensors
- Limit switch
- Photoelectric
- Tactile
- Proximity
- Temperature
- Pressure
- Flow

V. Operate the Following Positioners and Work Holders
- Hydraulic
- Electric
- Pneumatic
- Mechanical
- Index tables

VI. Set Up and Operate the Following Energy Control Devices
- Switches
- Relays
- Valves
- Servo
- Nonservo

VII. Evaluate Applications of the Following Types of Actuators
- Cylinders
- Rotary devices
- Stepper motors
- Mechanical
- Springs
- Solenoids

VIII. Assemble and Study Mechanical Positioners Operated by the following
- Four-bar linkages
- Geneva mechanisms
- Links
- Gears/pulleys
- Cam and follower
- Walking beams

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Program stepper motors.
2. Install, adjust, troubleshoot and repair or replace tactile and video sensors.
3. Describe the application of mechanical linkages/gears to a robotic work cell.
4. Perform electrical adjustments on servo power amplifiers.
5. Describe the application of hydraulic, electric or pneumatic positioners and sensors to a flexible cell.

CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS

Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students will learn the principles of control systems and how they are applied to a product on system to achieve automation. Systems included in the course are drum controllers, stepper motors, programmable logic controllers, microprocessors, computers, feedback systems and robot controllers.

COURSE OUTLINE

		Student Contact Hours	
		Class	Laboratory
I.	Introduction to Controllers	2	
	A. Purpose/Function of Controllers		
	B. Open-Loop Controllers		
	C. Closed-Loop Controllers		
II.	Fixed Sequence	8	18
	A. Ladder Diagrams		
	B. Drum Controllers/Timer		
	C. Stepper Relays		
III.	Programmable Logic Controllers (PLC)	3	12
	A. Sequence Controller		
	B. Process Controller		
	C. Components/Architecture of PLC		
IV.	Feedback Sensors	3	15
	A. Discrete Signals/Sensors		
	B. Analog Signals/Sensors		
	C. Contact Sensors		
	D. Noncontact Sensors		
	E. Output Signal Uses		
V.	Robot Controllers	4	15
	A. Definition of a Manufacturing Operation		
	B. Sensing		
	C. Controller Programming		
	D. Operation		
	E. Robot Controller Programming --A Case Study		

STUDENT LABORATORIES

I. Set Up, Program and Operate Drum Controllers

II. Set Up, Program and Operate Stepper Motors/Relays

III. Set Up, Program and Operate Open- and Closed-Loop Programmable Logic Controllers

IV. Set Up, Calibrate and Operate Feedback Sensors and Control Devices Including Encoders and Resolvers

V. Set Up and Operate Robot Controllers using:
Teach pendants
Walk through
Off line
Post process

STUDENT COMPETENCIES

Upon completion of this course, the student will be able to:

1. Install, adjust, troubleshoot and repair or replace control devices to manufacturer's specifications.
2. Program stepper relays.
3. Program and/or reprogram PLCs (drum, relay and microprocessor types) for specific sequence of events.
   a. Prepare a flow chart for a specific sequence of events in performing a given application.
   b. Enter instructions into control unit.
   c. Run program to see if it executes properly.
   d. Edit or debug program as necessary.
   e. Download and upload programs.
   f. Recognize and resolve hardware/software impedance matching problems.
4. Draw logic diagrams.
5. Read, understand and comply with requirements of service bulletins.
6. Use teaching pendant for testing, editing and setup.
7. Adjust feedback loops that include:
   a. Encoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessors
   e. Optoelectronics
   f. Hall-effect devices
   g. Velocity sensors
   h. Position detectors
8. Install a programmable controller and its input/output devices.
9. Perform electrical adjustments on servo power amplifiers.
10. Perform zeroing of encoders.
11. Define axis control and feedback specifications.

ROBOTICS/AUTOMATED SYSTEMS AT WORK
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

This course provides students an opportunity to observe and study the application of robots and automated systems applied to manufacturing. Students will simulate in the lab several of the systems observed in industry. The laboratory exercises are aimed at evaluating current systems and attempting to improve them.

COURSE OUTLINE	Student Contact Hours Class	Laboratory
I. Review Two Types of Automation A. Fixed B. Flexible	2	4 (field trips)
II. Flexible Automation A. Case Studies (Class) 1. Welding 2. Assembly 3. Material handling B. Case Study (Individual) Machine tending	10	42
III. Fixed Automation A. Case Studies (Class) 1. Bottlers 2. Transfer line 3. Photocopier B. Case Study (Individual) 1. Process control 2. Packaging	8	14

STUDENT LABORATORIES

I. Set up, Debug, Program, Operate Robots in Two Categories. (Electric, pneumatic, or hydraulic).
   a. Point-to-point, continuous path, control path
   b. Circular, spherical, cartesian, jointed spherical
   c. Drum, PLC, microprocessor, computer

II. Perform an Analysis of an Existing Automated System.

III. Assemble Prototype Systems Similar to Existing Production Systems.

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Install, adjust, troubleshoot and repair or replace sensors for tactile sensing.
2. Identify and use appropriate lubricant.
3. Use manual's troubleshooting charts to aid fault isolation/repair.
4. Explain the difference between accuracy, precision and repeatability.
5. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
6. Interconnect robots and other equipment.
7. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
8. Start up and debug a robot system.
9. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.
10. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
11. Specify the robot-to-material interfaces.
12. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place then on a transfer line.
13. Design a system for counting regular/irregular-shaped objects moving on an overhead track.
14. Operate the following equipment.
    a. End-of-arm tooling
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices
15. Adapt the following to robotic application:
    a. Welder
    c. Paint sprayers
    b. Adhesive applicators
    d. Grinders
16. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders

ROBOTICS AND AUTOMATED SYSTEMS INTERFACES
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students in this course will learn the principles of interconnecting (interfacing) controllers, sensors and actuators. They will study, set up and operate simple (discrete, binary) and complex (analog) sensors, tooling, controllers and network interfacing.

COURSE OUTLINE	Student Contact Hours Class	Laboratory
I. Simple Sensor Interfaces (Discrete, Binary) A. Sensors B. Controllers	4	12
II. Control Signal Interfacing A. Electrical Characteristics B. RS-232 Characteristics C. Data Transmission D. Terminology	4	12
III. Mechanical Interfaces A. Interchangeability B. Grippers C. Welders D. Applicators E. Grinders F. Lasers	4	12
IV. Electrical Interfaces A. Interchangeability B. Magnetic Pickups C. Grippers with Tactile Sensors D. Welders	4	12
V. Networking A. Data Exchange B. Control of Other Computers/Controllers	4	12

STUDENT LABORATORIES

I. Interface Signals
   a. Measure sensor output and compare to manufacturer's specifications.
   b. Simulate signals input to controller and observe and measure the response.
   c. Compare and analyze RS-232C interconnections and determine requirements for compatibility.

II. Tooling Interfaces
    a. Mechanical
        1. Interchangeability
        2. Movements/clearances
        3. Special hardware/tools of installation
    b. Electrical
        1. Power supplied
        2. Control signals
        3. Actuator/sensor sensing
        4. Disconnects
    c. Pneumatic/hydraulic
        1. Disconnects
        2. Pressure/volume flow
        3. Sensing

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Use manual's troubleshooting charts to aid fault isolation/repair.
2. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.
3. Use manufacturer's manuals to determine a machine's normal operating characteristics.
4. Using a manual, identify operational/functional systems.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
    a. Industrial robots
    b. End-of-arm tooling
    c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Start up and shutdown an automated production system.
10. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
11. Specify the robot-to-material interfaces.
12. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.
13. Set up, and so forth, robot to either remove parts from a conveyor and palletize them or to depalletize parts and place them on a conveyor.
14. Configure a system for counting regular/irregular-shaped objects moving on an overhead track.
15. Operate the following equipment:
    a. End-of-arm tooling
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices

16. Adapt the following to robotic application:
    a. Welder
    b. Adhesive applicators
    c. Paint sprayers
    d. Grinder
17. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders
18. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
19. Interchange different open-loop controllers between systems.
20. Interchange different closed-loop controllers between systems.

AUTOMATED WORK CELL INTEGRATION
Classroom/Laboratory hrs/wk 1/8

COURSE DESCRIPTION

Students, working in teams and under the instructor's supervision, will assemble and operate an automated production system. The students will select equipment, write specifications, design fixtures and interconnects, integrate system/provide interfaces, and make the assigned system operational. This is a laboratory class.

COURSE OUTLINE	Student Contact Hours	
	Class	Laboratory
The instructor will assign a work cell project. Students will analyze the requirements, write specifications and assemble, program, debug and operate a prototype or demonstration work cell.	10	80

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Interconnect robots and other equipment.
2. Program a host computer that controls the operation of several pieces of equipment.
3. Set up, operate, troubleshoot, maintain and repair automated systems.
4. Use manual's troubleshooting charts to aid fault isolation/repair.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Set up machine vision system.
10. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
11. Start up and shutdown an automated production system.
12. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
13. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
14. Develop material handling specifications for a work cell.
15. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.

16. Set up, and so forth, robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.
17. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
18. Write material handling specifications for a work cell.

APPENDIX C

A DESCRIPTION OF UTC PHYSICS

Unified Technical Concepts in Physics--or UTC Physics for short--is a course of instruction for technicians at the postsecondary level. It is a carefully selected and organized assembly of text and laboratory course materials. It is intended to organize technical principles in such a manner as to make them readily understood and applicable in different technologies--those that include electrical, mechanical, fluid, and thermal systems, and combinations thereof. It is intended to blend useful technical principles with laboratory practice on realistic devices that technicians use in their everyday work. It is NOT intended for students who plan to pursue physics as a career, or those who intend to become scientists or engineers. For those students, the traditional texts and courses in physics will continue to serve their needs.

The traditional format for presentation of technical physics has long been the bound textbook, logically divided into chapters that address, in turn, the separate disciplines of mechanics, heat, sound, wave motion, electricity, magnetism, and optics. But for technicians who generally take only one course in physics--as an important foundation course--this format has several inherent weaknesses. First, while mastering physics in the usual "compartments"--mechanics, heat, sound, etc.--the technician may miss important concepts that have analogous relationships that thread through the separate disciplines of mechanics, heat, hydraulics, and electricity. For example, the student may identify the physical concept of rate with speed (length/time), as it is usually introduced in mechanics, and not identify the rate analogies calories per second in thermal systems, square feet per second in hydraulic systems, and coulombs per second in electrical systems. Second, while spending undue time on formula derivation and proofs--a practice considered essential in traditional physics courses--the technician may miss the underlying message contained in important application of technical principles to useful devices and instruments in the scientific and industrial world.

In content, UTC Physics is similar to a traditional course in technical physics. Each course covers the body of knowledge called physics. But, in format, organization and manner of presentation, UTC Physics is significantly different. UTC Physics is a modular system of instruction. It consists of **concept** modules, **application** modules, and **supplementary** modules. The thrust of presentation in the concept modules is strongly one of unification of basic physics concepts in four major disciplines--mechanical, fluid, thermal, and electrical. And most importantly, through the use of specially

designed laboratory experiments in application modules, hands-on experience for the technician is heavily emphasized.

UTC Physics has been compiled into three books. The textual material--the **concept** modules are presented in a separate text. There are thirteen concept modules in all, each identified as an important technical base needed by today's technician. In order of presentation the technical concepts are: FORCE, WORK, RATE, MOMENTUM, RESISTANCE, POWER, ENERGY, FORCE TRANSFORMERS, ENERGY CONVERTORS, TRANSDUCERS, VIBRATIONS AND WAVES, TIME CONSTANTS, and RADIATION. While the first seven concepts are easily recognized as basic to physics, the balance, especially ENERGY CONVERTORS, TRANSDUCERS, and TIME CONSTANTS are not generally given headline coverage in traditional physics courses. But we have found them to be important for technicians.

We strongly advocate one year of UTC physics for the technician, with careful coverage of all thirteen concept modules, complemented by lab experiences from 60 to 90 application modules. However, for programs where only one-half of a year of physics--rather than the traditional full year--is available, we recommend that a total of seven concept modules and 40 to 60 application modules be covered. The concepts would include, in order: FORCE, WORK, RATE, RESISTANCE, POWER, ENERGY, and FORCE TRANSFORMERS.

Each of the thirteen concept modules begins with a development of the basic physics relevant to the physics concept in question. Then, the basic physics concept is identified as a unifying principle that is extended to a variety of problems in mechanical, thermal, fluid, and electrical systems. For example, the concept module on FORCE first covers the basic idea of a "force." It begins with the traditional definition of a "push or a pull" and moves on to applications involving Newton's laws of motion. But, in addition, the idea of force as a unifying concept is introduced and extended to thermal systems, hydraulic systems, and electrical systems. The module shows, for example, that a temperature difference (ΔT), a pressure difference (ΔP), and a voltage difference (ΔV) all behave like forces, even though these quantities are not forces in the strict sense of a "push or a pull"; nor do they have the usual units of a force, e.g., newtons. In this manner, the concept of FORCE is extended beyond the simple idea of a push or a pull in mechanical systems, and shown to be a useful, unifying concept that aids the student in understanding forces and motion in thermal, hydraulic, and electrical systems. This general pattern of defining and explaining each concept--and then demonstrating its application as a unifying concept in mechanical, fluid, thermal, and electrical systems--is continued throughout the text for each of the remaining 12 concepts.

A supplement has been developed and is included in the concepts volume for students who may have a deficiency in elementary mathematics or

laboratory skills. These supplementary modules are also useful for self-study or rapid review with instructor assistance.

There are 170 laboratory exercises available in the form of **application** modules, of which 150 of the most used have been presented in Volumes I and II, the applications volumes. They have been appropriately designed in the fields of mechanics, fluids, heat, vibrations, electricity and optics to illustrate real-world applications of the concept modules. Each application module describes an important application of a physical principle to a common piece of equipment. For example, to illustrate an important application of a technical principle, application modules use shock absorbers, prony brakes, strain gages, venturi meters, and electric motors in place of the traditional vibrating springs, inclined planes, pith balls, and air tables. The modules are carefully designed to emphasize hands-on laboratory experience.

In summary, UTC Physics is a modular system of instruction designed for technicians at the postsecondary level. It is built around basic technical concepts that form the foundation of the course. It offers a wide choice of application modules that exploit "hands-on" learning to apply the basic principles of physics to specialized areas of modern technology.

APPENDIX D

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